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(54) RADIO RECEIVER AND METHOD OF RECEPTION

(57) Signals received from antennas are input to weighting factor calculation sections 105 and 106. Weighting factor calculation section 105 calculates weighting factors so as to eliminate an interference signal using the antenna reception signals and known signals of a desired signal. Weighting factor calculation section 106 sequentially updates weighting factors so as to minimize the difference between a combined signal and its reference signal using the weighting factors calculated by weighting factor calculation section 105 as the initial values. On the other hand, reception quality measurement section 108 measures the reception quality of the combined signal and outputs the measurement result to weighting factor switching section 107. After receiving the measurement result, weighting factor switching section 107 switches weighting factors to be used for combination at the time the reception quality changes.

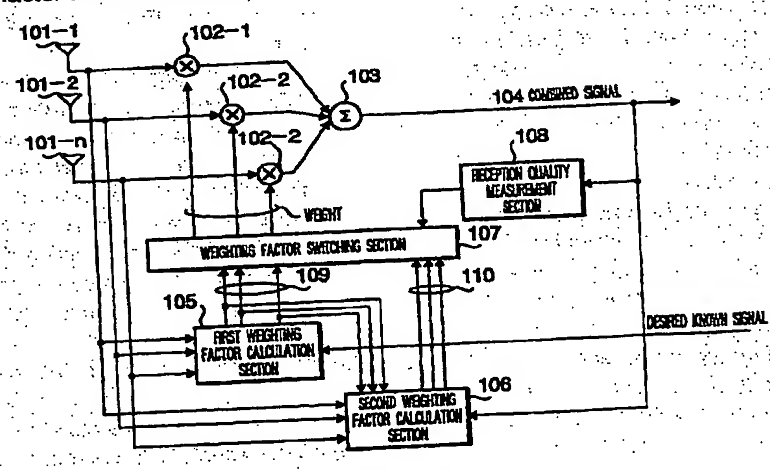

FIG. 4

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Description

Technical Field

[0001] The present invention relates to an apparatus and method for radio reception equipped with an adaptive array antenna capable of controlling directivity.

Background Art

[0002] An adaptive array antenna is known as an antenna system that can control directivity. "Waveform Equalization Technology for Digital Mobile Communications" (compiled under the supervision of Jun Horikoshi, Triceps Co., Ltd.) describes that in an array antenna consisting of a plurality of antennas, applying an amplitude/phase shift to the output of each antenna and then combining them will change the directivity of the array. The adaptive array antenna uses the principle above, and adaptively controls directivity in accordance with changes in surrounding conditions by determining a weighting factor of each antenna output based on a certain control algorithm and multiplying each antenna output by this weighting factor.

[0003] FIG.1 is a block diagram showing a configuration of a conventional adaptive array antenna apparatus (hereinafter referred to as "reception adaptive array"). As shown in the figure, antenna outputs 2 of a plurality of antennas 1 are multiplied by weighting factors 3 respectively and the antenna outputs weighted with these weighting factors 3 for respective antennas are combined into array output 4.

[0004] Weighting factors for their respective antenna outputs are controlled by weighting factor control section 5. Weighting factor control section 5 uses three kinds of information to control weighting factors; array combined output 4, respective antenna outputs 2 and advance knowledge 6 regarding a desired signal. There is also a system that does not use array output 4 to control weighting factors.

[0005] Conventionally, a weighting factor control algorithm assuming synchronous interference is applied to weighting factor control section 5. In a weighting factor control algorithm assuming synchronous interference, weighting factors are controlled so as to eliminate such an interference signal that is present continuously during the interval from the beginning to the end of a desired signal (hereinafter referred to as "synchronous interference") as shown in FIG.2.

[0006] However, if a signal provided by a communication user who is different from the communication user who is transmitting the desired signal is the interference signal, synchronization between the desired signal and interference signal is not guaranteed, and there is a possibility that the interference signal will mix into the desired signal at some midpoint as shown in FIG.3.

[0007] Thus, the conventional system has the problem that if the interference signal mixes into the desired signal at some midpoint the weighting factors calculated using a known signal of the desired signal before the interference signal starts to interfere cannot fully eliminate the interference signal.

Disclosure of Invention

[0008] It is an objective of the present invention to provide an apparatus and method for adaptive array antenna radio reception that can appropriately control weighting factors for array combination and effectively eliminate or suppress an interference signal even if the interference signal mixes into a desired signal at some midpoint.

[0009] This objective is achieved by a radio reception apparatus comprising a combination section that weights and then combines reception signals corresponding to a plurality of antenna elements respectively and a factor adaptation section that adaptively controls weighting of the reception signals above according to the time at which the interference signal mixes into the desired signal.

Brief Description of Drawings

[0010]

FIG 1 is a block diagram showing a configuration of a conventional adaptive array antenna reception apparatus;

FIG.2 is a diagram showing a case where an interference signal continuously interferes with a desired signal;

FIG.3 is a diagram showing a case where an interference signal mixes into a desired signal at some midpoint;

FIG.4 is a block diagram showing a configuration of an adaptive array antenna reception apparatus according to Embodiment 1 of the present invention;

FIG.5 is a block diagram showing a configuration of an adaptive array antenna reception apparatus according to Embodiment 2 of the present invention;

FIG.6 is a diagram showing a slot configuration of a radio communication system according to Embodiment 3 of the present invention;

FIG.7 is a diagram showing a combination direction according to the position of a known signal in the first part according to Embodiment 3; and

FIG.8 is a diagram showing a combination direction according to the position of another known signal in the latter part according to Embodiment 3.

Best Mode for Carrying out the Invention

[0011] With reference now to the attached drawings, the embodiments of the present invention are explained

in detail below.

(Embodiment 1)

[0012] FIG.4 is a block diagram showing a configuration of an adaptive array antenna reception apparatus according to Embodiment 1 of the present invention. This adaptive array antenna reception apparatus inputs reception signals output from a plurality of antenna elements 101-1 to 101-n to their respective multipliers 102-1 to 102-n where those reception signals are multiplied by weighting factors (weights). Then, adder 103 combines the signals output from multipliers 102-1 to 102-n into combined signal 104 which becomes array output.

[0013] The weights multiplied on the reception signals are calculated by either first weighting factor calculation section 105 or second weighting factor calculation section 106. Weighting factor switching section 107 selects weighting factors calculated by either first weighting factor calculation section 105 or second weighting factor calculation section 106 and gives these weighting factors to multipliers 102-1 to 102-n. Weighting factor switching section 107 controls switching based on the reception quality measurement result of combined signal 104 which is the array output input from reception quality measurement section 108.

[0014] Then, the operation of the adaptive array antenna reception apparatus configured as shown above is explained in detail below.

[0015] The reception signals received from antenna elements 101-1 to 101-n are input to first weighting factor calculation section 105 and second weighting factor calculation section 106. First weighting factor calculation section 105 calculates weighting factors 109 such that eliminate an interference signal using the antenna reception signals and known signals of a desired signal. Second weighting factor calculation section 106 calculates weighting factors 110 and updates them sequentially so as to minimize the difference between combined signal 104 and its reference signal using weighting factors 109 calculated by first weighting factor calculation section 105 as the initial values.

[0016] In the case of the synchronous interference shown in FIG.2, a desired signal, which is the reception signal stripped of an interference signal, is obtained by multiplying the antenna reception signals by corresponding weighting factors 109 calculated by first weighting factor calculation section 105 and then combining them.

[0017] This is because the known signal part of the reception signals when first weighting factor calculation section 105 calculates weighting factors 109 contains both a desired signal and an interference signal and the weighting factors obtained from there can extract only the desired signal by eliminating the interference signal from the reception signals.

[0018] On the other hand, in the case of the asynchronous interference shown in FIG.3, the known signal part of the reception signals does not contain an interference signal, and the weighting factors obtained from there cannot eliminate the interference signal that interferes later, and therefore the reception quality deteriorates at the time the interference signal starts to interfere.

[0019] In order to cope with such asynchronous interference, the present embodiment sequentially updates weighting factors 110 at second weighting factor calculation section 106 and switches the weighting factors to be multiplied on the antenna reception signals from weighting factors 109 to weighting factors 110 at the time the interference signal starts to interfere. By adaptively switching weighting factors in this way, the present embodiment can eliminate or suppress an interference signal contained in the antenna reception signals and extract a desired signal even in the case of asynchronous interference.

[0020] Then, reception quality measurement section 108 measures the reception quality of combined signal 104 and inputs the measured value to weighting factor switching section 107. Weighting factor switching section 107 determines the time at which the quality of combined signal 104 changed from the reception quality measured value and switches the weighting factors to weighting factors 110 output from second weighting factor calculation section 106 at that time.

[0021] As shown above, Embodiment 1 of the present invention can effectively eliminate interference signals in both the case of synchronous interference shown in FIG.2 and the case of asynchronous interference shown in FIG.3, that is, not only the case where an interference signal exists from the beginning but also the case where an interference signal mixes into a desired signal at some midpoint. This makes possible adaptive array reception using weighting factors that optimize the reception quality even if an interference signal exists, making it possible to effectively suppress an interference signal and extract a desired signal.

[0022] In the algorithm that sequentially updates weighting factors used in second weighting factor calculation section 106, the amount of calculation tends to become enormous, but using the configuration that allows the switching of the weighting factor calculation sections as shown in the present embodiment makes it possible to use the algorithm only when it is necessary and thus reduce the time and memory, etc. required to calculate weighting factors.

[0023] In Embodiment 1 above, second weighting factor calculation section 106 sequentially updates weighting factors 110 so as to minimize the difference between the combined signal and its reference signal, but the above means is not essential in the present invention and it is obvious that weighting factors can be calculated by other means that do not use known signals.

[0024] Furthermore, the present embodiment described the case with two weighting factor calculation sections, but the number of weighting factor calculation sections is not limited to 2; more weighting factor calcu-

lation sections can also be added.

[0025] Moreover, the present embodiment described the case where second weighting factor calculation section 106 uses the weighting factors calculated by first weighting factor calculation section 105 as the initial values, but this need not always be followed; arbitrary constants can also be used and antenna reception signals can also be combined using weighting factors from second weighting factor calculation section 106.

(Embodiment 2)

[0026] FIG.5 shows a configuration example of an adaptive array antenna radio reception apparatus according to Embodiment 2 of the present invention. The parts that have the same functions as those of the adaptive array antenna radio reception apparatus shown in FIG.4 are assigned the same numbers.

[0027] The present embodiment detects the interference mixed position of an interference signal from antenna reception signals prior to combination to acquire timing for switching weighting factors.

[0028] The adaptive array antenna radio reception apparatus according to the present embodiment inputs a plurality of antenna reception signals not only to first and second weighting factor calculation sections 105 and 106 but also to interference mixed position detection section 200. Interference mixed position detection section 200 performs correlation detection using known signals of an interference signal for the start to end of antenna reception signals (the start to end of a transmission unit such as 1 slot or cell, etc.). Interference mixed position detection section 200 predicts the position at which the highest correlation value is detected as the interference mixed position and outputs the predicted interference signal mixed position to weighting factor switching section 107'.

[0029] Then, the operation of the adaptive array antenna radio reception apparatus configured as shown above is explained in detail below.

[0030] Signals received from the antennas are input to first weighting factor calculation section 105, second weighting factor calculation section 106 and interference mixed position detection section 200. First weighting factor calculation section 105 calculates weighting factors 109 such that eliminate interference signals using the antenna reception signals and known signals of a desired signal. Second weighting factor calculation section 106 sequentially updates weighting factors 110 so as to minimize the difference between combined signal 104 and its reference signal using the weighting factors 109 calculated by first weighting factor calculation section 105 as the initial values.

[0031] In the case of the synchronous interference shown in FIG.2, a desired signal, which is the reception signal stripped of an interference signal, is obtained by multiplying the antenna reception signals by corresponding weighting factors 109 calculated by first weighting factor calculation section 105 and then combining them. This is because the known signal part of the reception signals when first weighting factor calculation section 105 calculates weighting factors contains both a desired signal and an interference signal and the weighting factors obtained from there can extract only the desired signal by eliminating the interference signal from the reception signals.

[0032] However, in the case of the asynchronous interference shown in FIG.3, the known signal part of the reception signals does not contain an interference signal, and the weighting factors obtained from there cannot eliminate the interference signal that interferes later, and therefore the reception quality deteriorates at the time the interference signal starts to interfere. In this case, the present embodiment does not use the known signals to calculate weighting factors, but sequentially updates weighting factors 110 at second weighting factor calculation section 106, thus making it possible to suppress the interference signal contained in the antenna reception signals and extract the desired signal.

[0033] Then, the antenna reception signals are input to interference mixed position detection section 200 where the start to end of the antenna reception signals is subjected to correlation detection using known signals of the interference signal. Interference mixed position detection section 200 predicts the position at which the highest correlation value is detected as the interference mixed position and outputs the predicted interference mixed position to weighting factor switching section 107'. If the detection position is behind an appropriate position, weighting factor switching section 107' switches weighting factors to be used for combination at that position to weighting factors 110.

[0034] As shown above, Embodiment 2 of the present invention can effectively eliminate or suppress interference signals in both the case of synchronous interference shown in FIG.2 and the case of asynchronous interference shown in FIG.3 by predicting the position at which an interference signal starts to interfere and switching the weighting factors from that position. Therefore, regardless of the time at which an interference signal mixes into a desired signal, if the interference signal exists in any known signal part of the antenna reception signal, it is possible to obtain a desired signal with the interference signal suppressed from the combined signal using the weighting factors calculated there.

[0035] The present embodiment uses correlation detection as a means for predicting the position at which an interference signal mixes into a desired signal, but this need not always be followed; it is also possible to predict the mixed position of an interference signal from the reception field intensity, for example.

(Embodiment 3)

[0036] In the radio communication system in the present embodiment, the transmitting side transmits by radio a transmission signal with known signals placed in a plurality of locations in a slot and the receiving side receives the transmission signal above, calculates weighting factors using the known signal parts where an interference signal exists, weights signals received from a plurality of antennas with these weighting factors calculated and combines them.

[0037] As shown in FIG.6, the transmission data has a slot configuration (frame format) where known signals 301 and 302 are placed in the first part and latter part, which allows the combination direction to be switched depending on which known signal part contains both a desired signal and interference signal, the first part or the latter part.

[0038] In the case of the synchronous interference shown in FIG.2, if the interference signal ceases to exist at some midpoint as shown in FIG.7, weighting factors are calculated using known signal part 301 in the first part of antenna reception signal. Since the known signal part in this first part contains both a desired signal and interference signal, weighting factors calculated using this part can suppress the interference signal. It is possible to extract the desired signal with the interference signal suppressed from the combined signal obtained from the antenna reception signals using those weighting factors.

[0039] Moreover, in a case where no interference signal exists in known signal 500 in the first part and there is an interference signal in known signal 501 in the latter part, weighting factors are calculated using known signal part 501 in the latter part. In this case, at least one slot of antenna reception signals is buffered, then weighting factors are calculated using known signal part 501 in the latter part and then the buffered antenna reception signals are combined using those weighting factors.

[0040] In this way, selection can be made from two demodulation methods; one in which weighting factors are calculated using the known signal in the first part of a slot (frame format) and these weighting factors are combined from the first part to the latter part, or from the latter part to the first part, and the other in which weighting factors are calculated using the known signal in the second part and these weighting factors are combined from the latter part to the first part, or from the first part to the latter part. In either case, it is possible to extract a desired signal from the combined signal with the interference signal suppressed.

[0041] Embodiment 3 uses a slot configuration (frame format) containing known signals in first part 301 and latter part 302, but it is possible to extract a desired signal if the known signal parts are placed so that an interference signal is captured whenever it starts to interfere.

[0042] It is also possible to adopt a configuration that calculates weighting factors using a known signal in the first part of the slot and another known signal in the latter part of the same slot, compares the reception qualities of both combined signals weighted with the weighting factors above and uses the combined signal weighted with the weighting factor with the better reception quality.

[0043] This configuration makes it possible to eliminate an interference signal by calculating weighting factors using the known signal in the first part in the case of synchronous interference, and using the known signal in the latter part in the case of asynchronous interference.

[0044] Furthermore, it is also possible to install the adaptive array antenna radio reception apparatus above in a mobile unit and/or base station apparatus and construct a radio system that carries out a radio communication between the mobile unit and base station.

[0045] As described in detail above, the present invention can effectively suppress an interference signal from a combined reception signal by adaptively selecting and switching weighting factors according to the time at which the interference signal mixes into a desired signal.

[0046] This application is based on the Japanese Patent Application No.HEI 10-102197 filed on March 30, 1998, entire content of which is expressly incorporated by reference herein.

Industrial Applicability

[0047] The radio reception apparatus of the present invention is applicable to a base station apparatus in a digital radio communication system.

Claims

1. A radio reception apparatus comprising:

   combination means for weighting and then combining signals received from a plurality of antennas; and
   factor adaptation means for adaptively controlling weighting on said reception signals according to the time at which an interference signal mixes into a desired signal.

2. The radio reception apparatus according to claim 1, wherein the factor adaptation means comprises:

   reception quality measurement means for measuring the reception quality from a combined signal output from the combination means; and
   switching means for switching, if the reception quality deteriorates, to weighting factors obtained from the reception signals after the deterioration.

3. The radio reception apparatus according to claim 1, wherein the factor adaptation means comprises:

position detection means for detecting the position at which the interference signal mixes into the desired signal; and
switching means for switching to weighting factors obtained from the reception signals at and after the position at which the interference signal starts to interfere.

4. The radio reception apparatus according to claim 3, wherein the position detection means comprises a correlator that finds correlation between the reception signals and interference signal.

5. The radio reception apparatus according to claim 1, said radio reception apparatus calculating weighting factors from the reception signals and known signals of the desired signal.

6. The radio reception apparatus according to claim 1, said radio reception apparatus updating weighting factors based on the difference between the combined signal and known signal, and reception signals.

7. A radio reception apparatus comprising:

combination means for weighting and then combining signals received from a plurality of antennas; and
weighting factor calculation means for calculating weighting factors using one of known signals placed in a plurality of locations in a slot that includes at least an interference signal.

8. The radio reception apparatus according to claim 7, wherein known signals are included in two locations; in the first and latter parts of the slot.

9. The radio reception apparatus according to claim 8, wherein weighting factors are calculated from a plurality of known signals placed in the slot.

10. The radio reception apparatus according to claim 9, said radio reception apparatus further comprising:

first weighting factor calculation means for calculating weighting factors from the known signal in the first part of the slot;
second weighting factor calculation means for calculating weighting factors from the known signal in the latter part of the slot; and
comparing means for comparing the reception quality of both combined signals weighted with the weighting factors calculated by said first and second weighting factor calculation means.

11. A radio reception method comprising the steps of:

weighting and then combining signals received from a plurality of antennas; and
adaptively controlling weighting on said reception signals according to the time at which an interference signal mixes into a desired signal.

12. The radio reception method according to claim 11, further comprising the steps of:

measuring the reception quality from a weighted and combined signal; and
switching, if the reception quality deteriorates, to weighting factors obtained from the reception signals after the deterioration.

13. The radio reception method according to claim 11, further comprising the steps of:

detecting the position at which the interference signal mixes into the desired signal; and
weighting the reception signals with weighting factors obtained from the reception signals at and after the position at which the interference signal starts to interfere.

14. The radio reception method according to claim 13, further comprising the step of detecting the position at which the interference signal starts to interfere by finding correlation between the reception signals and known signals of the interference signal.

15. A radio reception method comprising the steps of:

receiving a transmission signal with known signals placed in a plurality of locations in a slot;
calculating weighting factors using a known signal part where an interference signal exists; and
weighting the signals received from a plurality of antennas with these weighting factors calculated and then combining the weighted reception signals.

16. The radio reception method according to claim 15, further comprising the steps of:

calculating weighting factors from a certain known signal in the first part of the slot;
calculating weighting factors from another known signal in the latter part of the same slot; and
comparing the reception qualities of both combined signals weighted with said weighting factors.

17. A radio transmission apparatus transmitting a transmission signal with transmission data divided into slots and known signals placed in a plurality of locations in each slot to the radio reception apparatus according to claim 7.

18. A radio communication method comprising the steps of:

the transmitting side transmitting by radio a transmission signal with known signals placed in plurality of locations in a slot; and
the receiving side receiving said transmission signal, calculating weighting factors using a known signal part where an interference signal exists and weighting signals received from a plurality of antennas with the weighting factors calculated and combining these weighted reception signals.

19. A base station apparatus comprising a radio reception apparatus, said radio reception apparatus comprising:

combination means for weighting and then combining signals received from a plurality of antennas; and
factor adaptation means for adaptively controlling weighting on said reception signals according to the time at which an interference signal mixes into a desired signal.

20. A communication terminal apparatus carrying out a radio communication with a base station apparatus, said base station apparatus comprising:

combination means for weighting and then combining signals received from a plurality of antennas; and
factor adaptation means for adaptively controlling weighting on said reception signals according to the time at which an interference signal mixes into a desired signal.

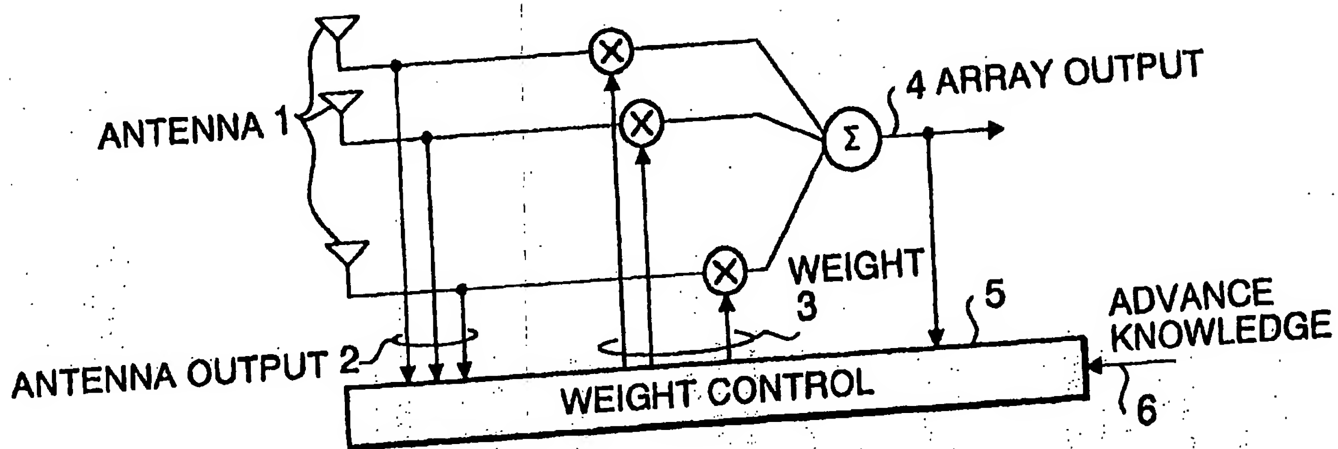

ANTENNA 1
4 ARRAY OUTPUT
Σ
WEIGHT
3
5
ADVANCE
KNOWLEDGE
6
ANTENNA OUTPUT 2
WEIGHT CONTROL

FIG. 1

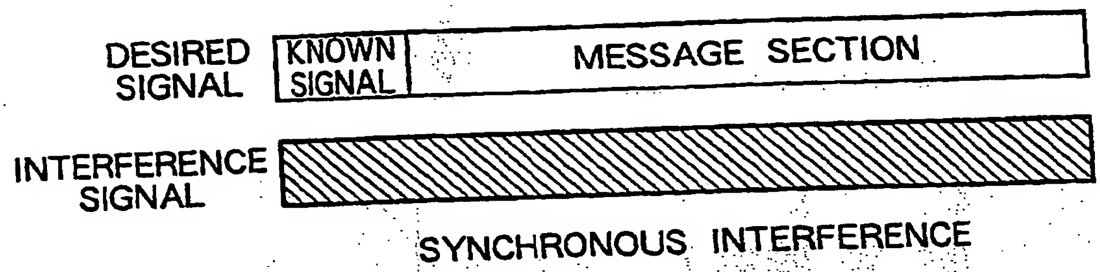

DESIRED SIGNAL
KNOWN SIGNAL
MESSAGE SECTION
INTERFERENCE SIGNAL
SYNCHRONOUS INTERFERENCE

FIG. 2

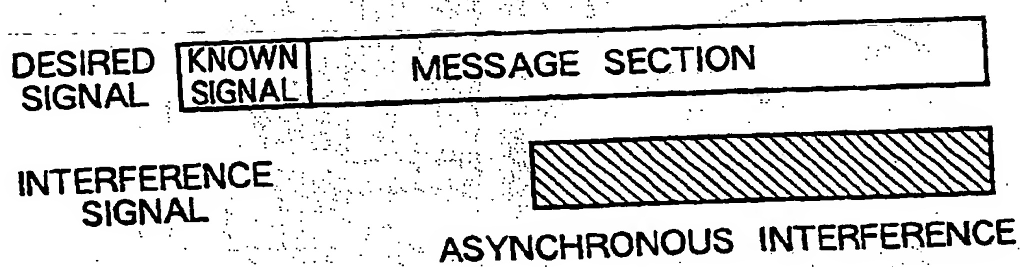

DESIRED SIGNAL
KNOWN SIGNAL
MESSAGE SECTION
INTERFERENCE SIGNAL
ASYNCHRONOUS INTERFERENCE

FIG. 3

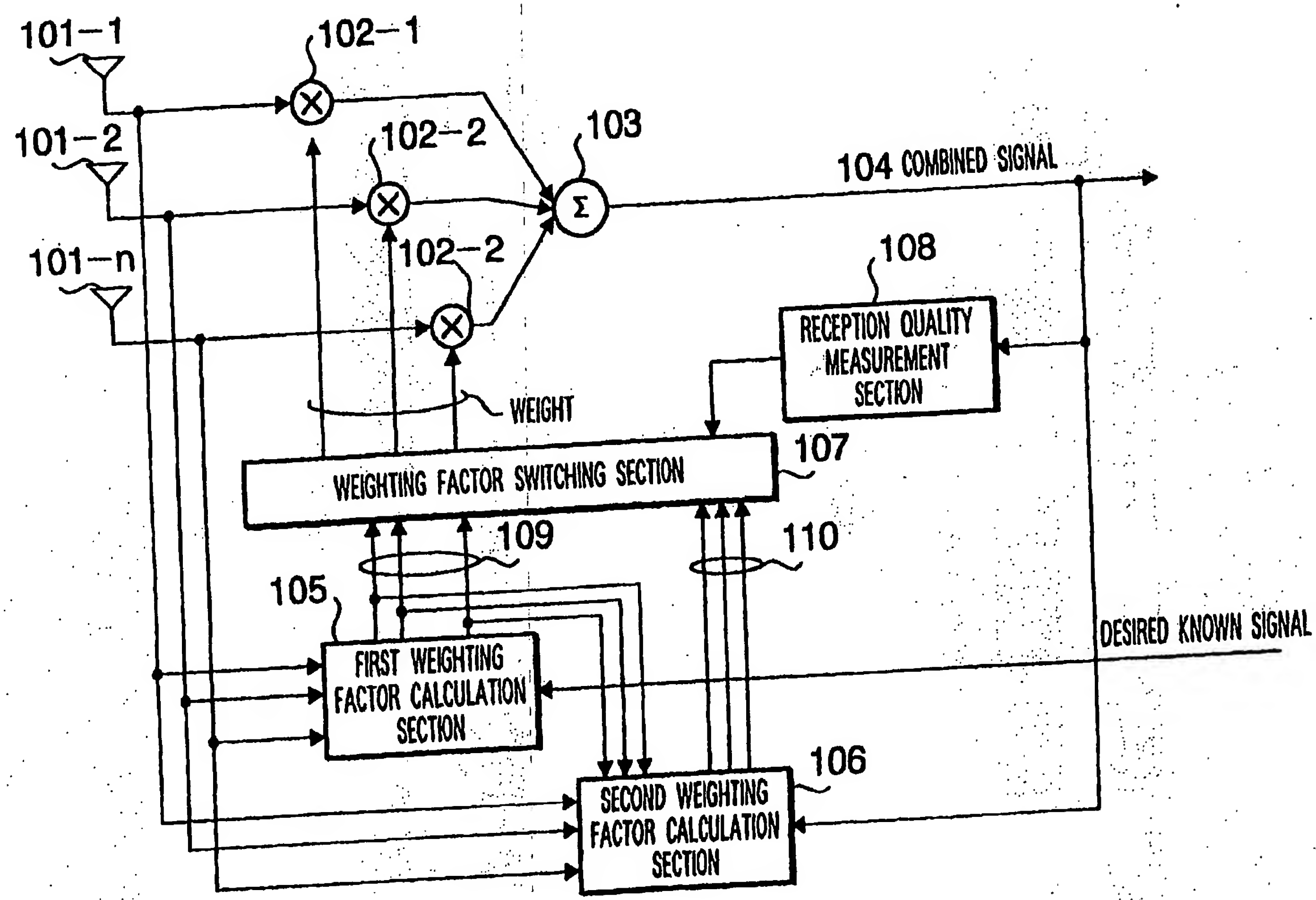
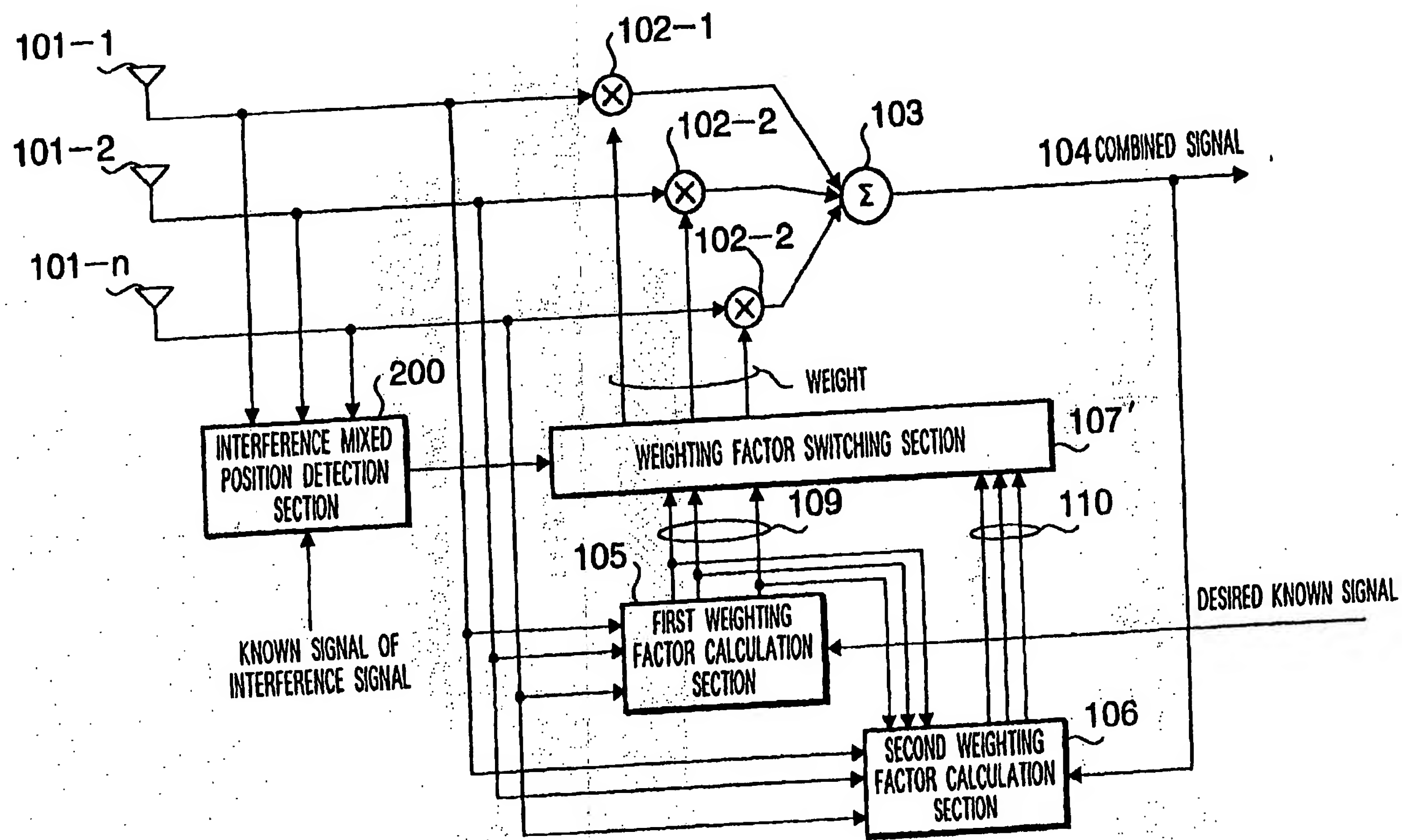

101–1
101–2
101–n
102–1
102–2
102–2
103
104 COMBINED SIGNAL
108
RECEPTION QUALITY MEASUREMENT SECTION
WEIGHT
WEIGHTING FACTOR SWITCHING SECTION
107
109
110
105
FIRST WEIGHTING FACTOR CALCULATION SECTION
DESIRED KNOWN SIGNAL
106
SECOND WEIGHTING FACTOR CALCULATION SECTION

FIG. 4



101−1
101−2
101−n
102−1
102−2
102−2
103
Σ
104 COMBINED SIGNAL
200
INTERFERENCE MIXED POSITION DETECTION SECTION
KNOWN SIGNAL OF INTERFERENCE SIGNAL
WEIGHT
WEIGHTING FACTOR SWITCHING SECTION
107'
109
110
105
FIRST WEIGHTING FACTOR CALCULATION SECTION
DESIRED KNOWN SIGNAL
106
SECOND WEIGHTING FACTOR CALCULATION SECTION

FIG. 5

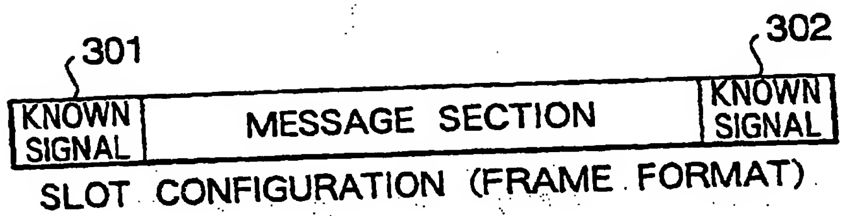

301
302
KNOWN SIGNAL
MESSAGE SECTION
KNOWN SIGNAL
SLOT CONFIGURATION (FRAME FORMAT)

FIG. 6

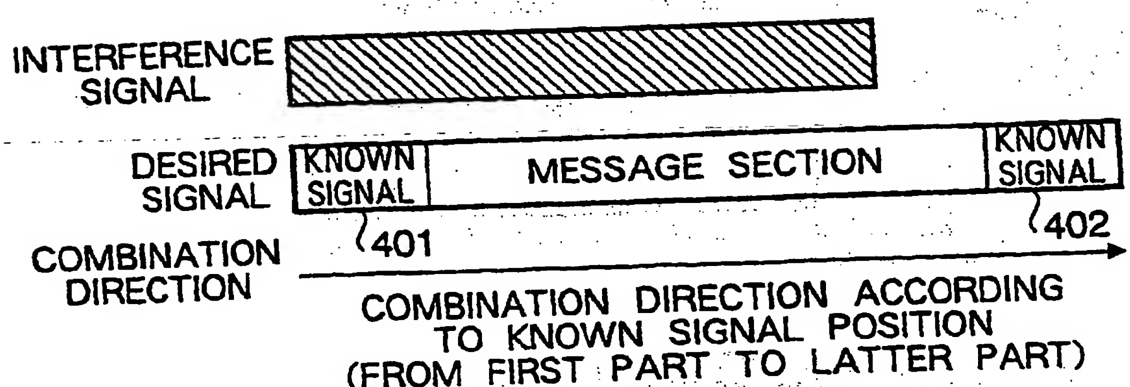

INTERFERENCE SIGNAL
DESIRED SIGNAL
KNOWN SIGNAL
MESSAGE SECTION
KNOWN SIGNAL
401
402
COMBINATION DIRECTION
COMBINATION DIRECTION ACCORDING TO KNOWN SIGNAL POSITION (FROM FIRST PART TO LATTER PART)

FIG. 7

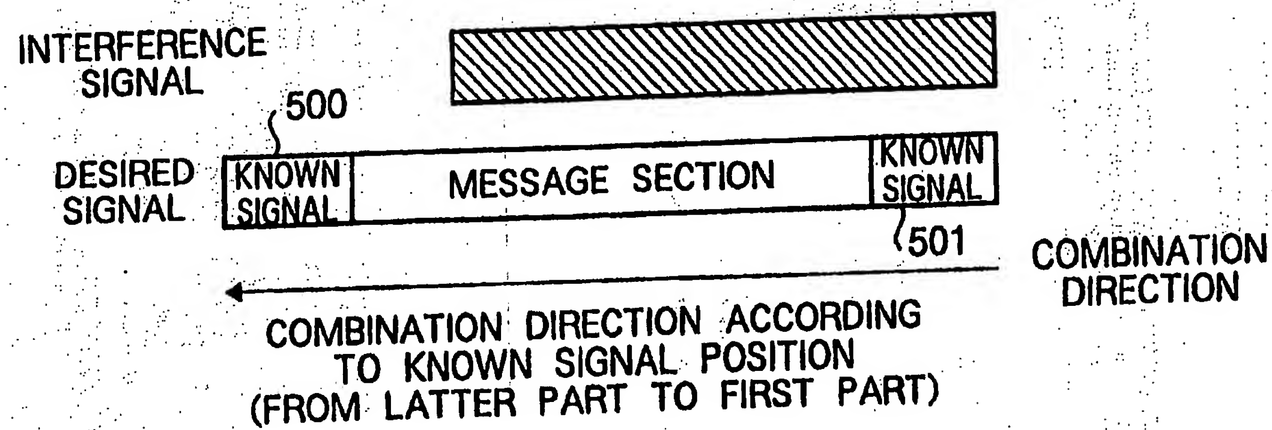

INTERFERENCE SIGNAL
500
DESIRED SIGNAL
KNOWN SIGNAL
MESSAGE SECTION
KNOWN SIGNAL
501
COMBINATION DIRECTION
COMBINATION DIRECTION ACCORDING TO KNOWN SIGNAL POSITION (FROM LATTER PART TO FIRST PART)

FIG. 8